

# Distributed Systems in Action

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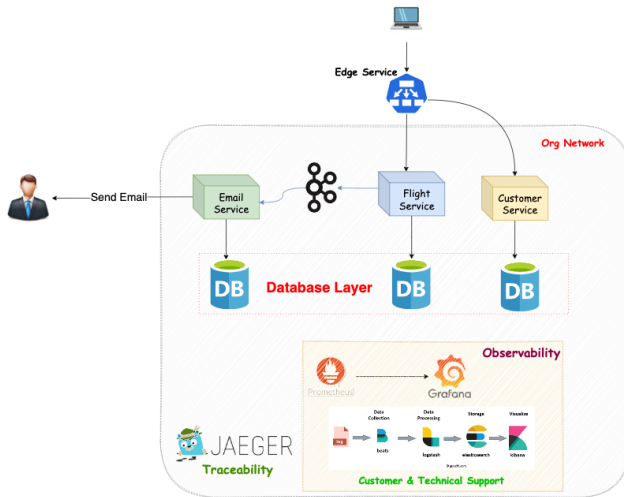
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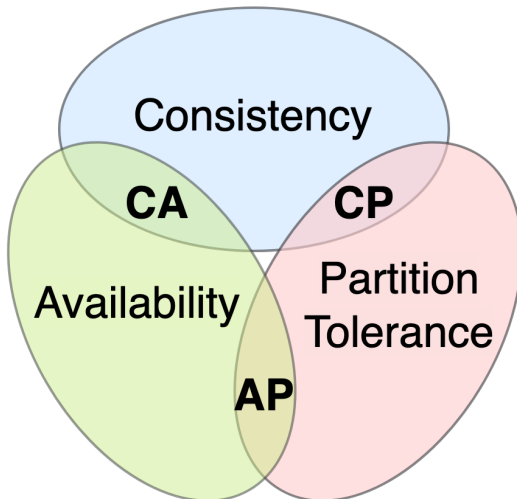
# Introduction to Distributed Systems

- Definition and characteristics of distributed systems
- Importance and benefits of distributed systems
- Challenges and trade-offs in designing distributed systems

# Use Case: Flight System

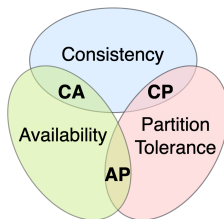


# CAP Theorem



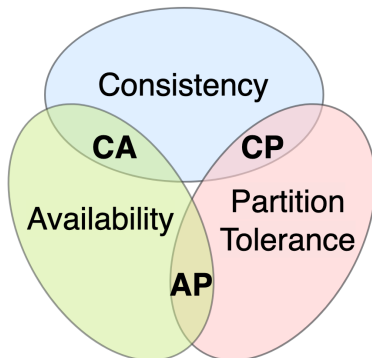
# Distributed Databases

- **Consistency** every read operation gives a result of the most recent write.
- **Availability** every read operation gives a non-error response, but, data might be staled.
- **Partition Tolerance** system operates normally despite network failure.



# Distributed Databases

In the presence of network partitioning, system designers must choose between data consistency and availability.



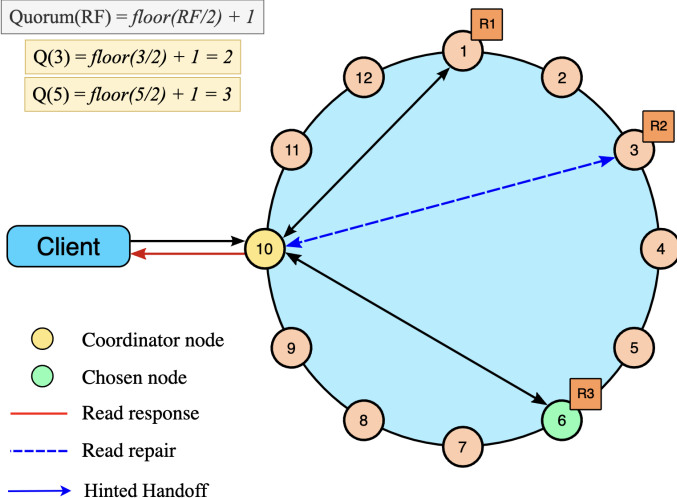
# Distributed Databases

Coordinator waits until Quorum acknowledge

$$\text{Quorum}(\text{RF}) = \text{floor}(\text{RF}/2) + 1$$

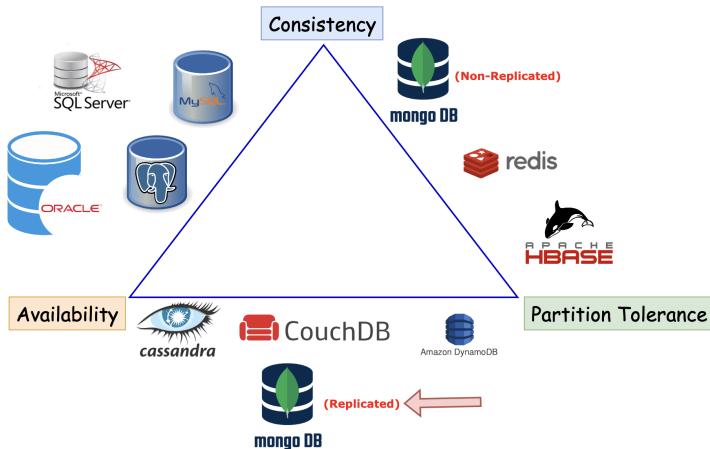
$$Q(3) = \text{floor}(3/2) + 1 = 2$$

$$Q(5) = \text{floor}(5/2) + 1 = 3$$



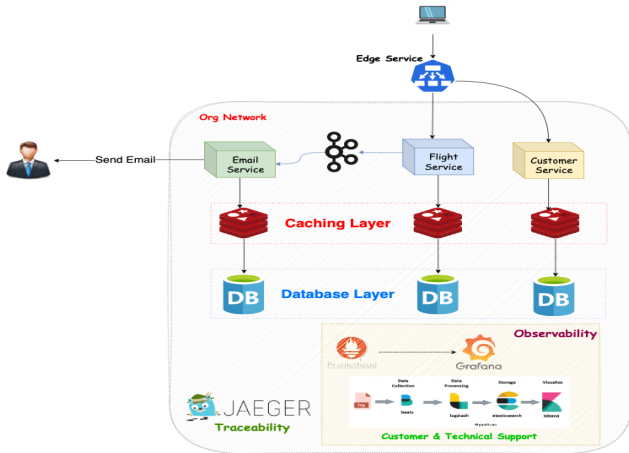


# Distributed Databases



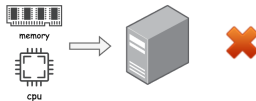
# High Availability and Scalability

- Load Balancer
- API Gateway
- Rate Limiter

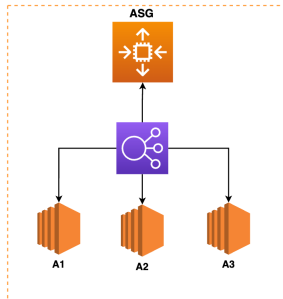
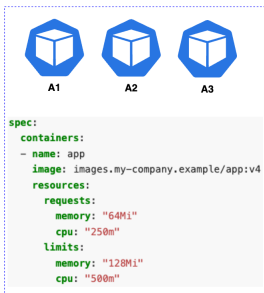


# Horizontal Scaling vs Vertical Scaling

## Vertical Scaling

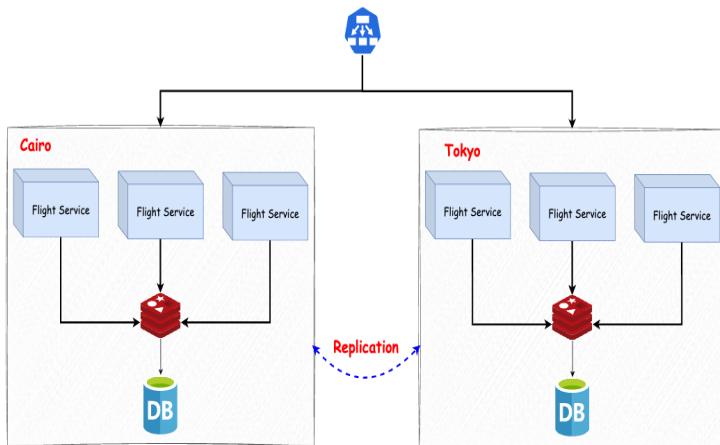


## Horizontal Scaling



```
spring:
  cloud:
    default-filters:
      - name: Retry
        args:
          retry: 5
          methods: GET
          backoff:
            firstBackOff: 10ms
            maxBackOff: 50ms
            factor: 2
            basedOnPreviousValue: false
```

# Data Replication

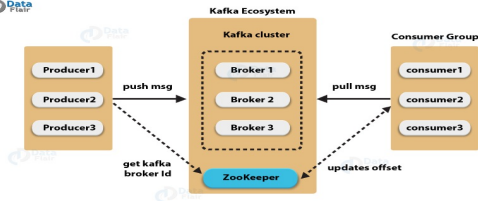
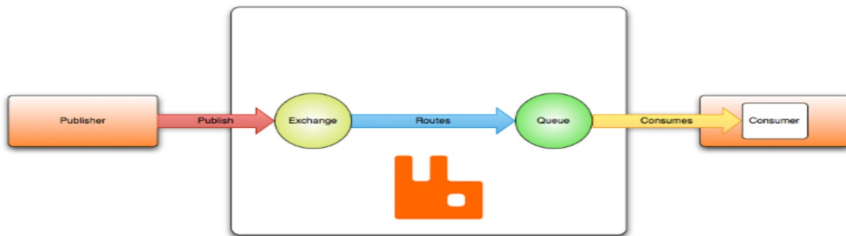


# Distributed Messaging Systems

- Introduction to distributed messaging systems
- Overview of Kafka and RabbitMQ

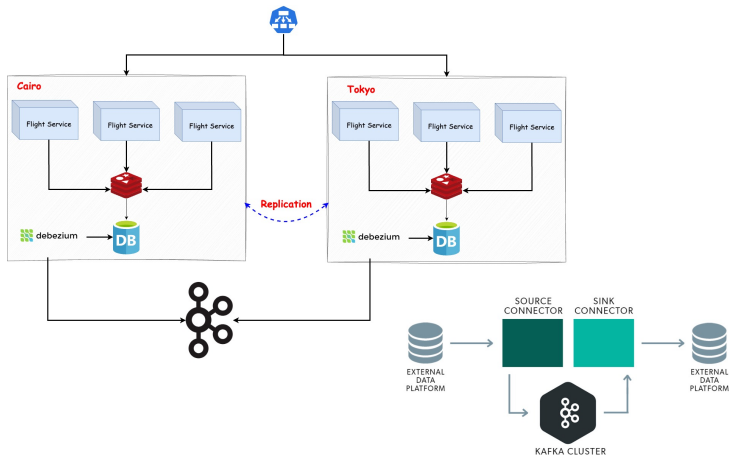
# RabbitMQ vs Kafka

## "Hello, world" example routing



# Data Replication: CDC

In databases, **change data capture (CDC)** is a set of *software design patterns* used to determine and track the data that has changed (the "deltas") so that action can be taken using the changed data.





# Data Replication: CDC

```
{
  "schema": {},
  "payload": {
    "source": {
      "version": "2.2.1.Final",
      "connector": "mysql",
      "name": "mysql",
      "db": "inventory",
      "sequence": null,
      "table": "customers"
    },
    "databaseName": "inventory",
    "schemaName": null,
    "ddl": "ALTER TABLE customers ADD middle_name varchar(255) AFTER first_name",
    "tableChanges": [
      {
        "type": "ALTER",
        "id": "\\\"inventory\\\".\\\"customers\\\".",
        "table": {
          "defaultCharsetName": "utf8mb4",
          "primaryKeyColumnNames": [
            "id"
          ],
          "columns": [
            {
              "name": "id",
              "jdbcType": 4,
              "nativeType": null,
              "typeName": "INT",
              "typeExpression": "INT",
              "charsetName": null,
              "length": null,
              "scale": null,
              "position": 1,
              "optional": false,
              "autoIncremented": true,
              "generated": true
            }
          ]
        }
      }
    ]
  }
}
```

# Distributed Messaging Systems

- Introduction to distributed messaging systems
- Overview of Kafka and RabbitMQ
- Comparison between Kafka and RabbitMQ:

Kafka	RabbitMQ
High-throughput, fault-tolerant distributed streaming platform.	Robust and flexible messaging broker.
Emphasizes real-time event streaming and data pipeline use cases.	Implements Advanced Message Queuing Protocol (AMQP).
Provides strong durability and replication guarantees.	Focuses on message queuing and asynchronous communication.
Scales horizontally to handle large-scale data streams.	Provides various messaging patterns (e.g., publish-subscribe, point-to-point).
Supports complex event processing with built-in stream processing.	Offers pluggable message durability, routing, and acknowledgement mechanisms.

# Distributed Key-Value Stores

A type of NoSQL DBs, the idea behind having **it** is having an extremely fast mechanism for retrieving the data.

- Introduction to distributed key-value stores (e.g., Redis, Memcached)
- Data partitioning and replication techniques
- Consistency and availability trade-offs

# Distributed Key-Value Stores: Memcached vs Redis

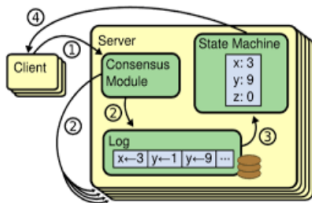


Memcached	Redis
In-memory key-value store primarily designed for caching.	In-memory key-value store with additional data structures and functionality.
Supports simple key-value operations like GET, SET, DELETE.	Offers a rich set of data structures (strings, lists, sets, hashes, sorted sets).
Lacks built-in persistence mechanisms.	Provides persistence options (snapshotting, append-only file, replication).
Does not support complex queries or secondary indexes.	Supports more advanced operations like sorting, ranking, and filtering.
Focuses on high performance and low latency.	Balances performance with additional functionality and data structures.
No built-in way of replication, requires additional component.	Come with out-of-the-box replication using cluster, and as feature with <b>Sentinel</b> .

# Consensus

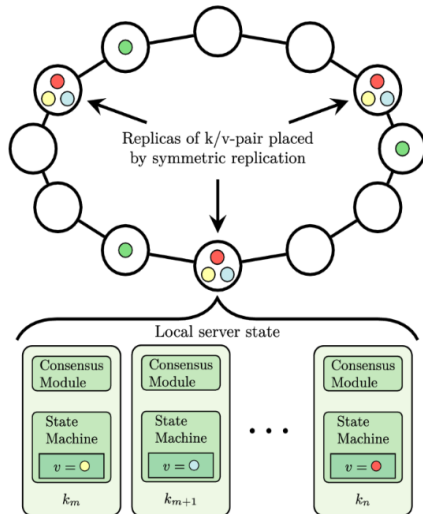
## Replicated State Machine

Implementing a fault-tolerant service by replicating servers and coordinating client interactions with server replicas



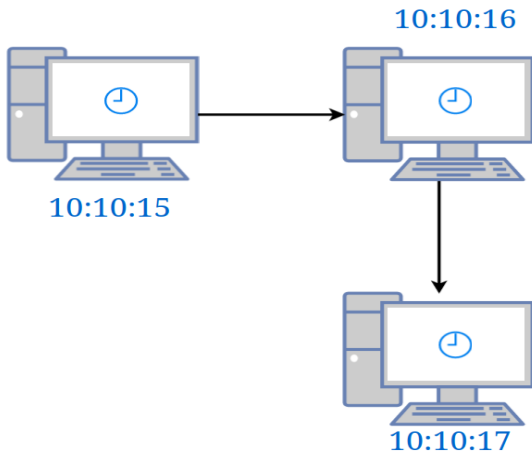
## Algorithms

- **Paxos**
- **Raft**



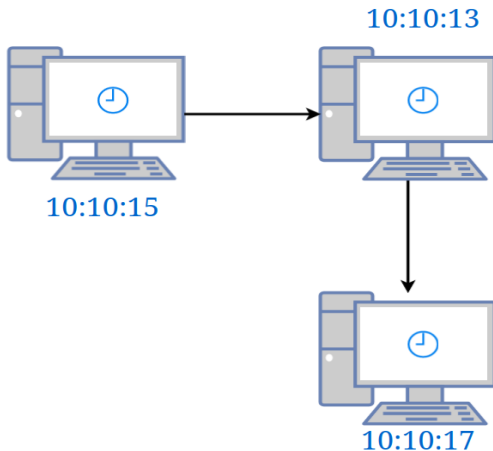
# Natural/Physical Clock

What is the order of the events?



# Natural/Physical Clock

What is the order of the events?



# Natural/Physical Clock

## Quartz Clock





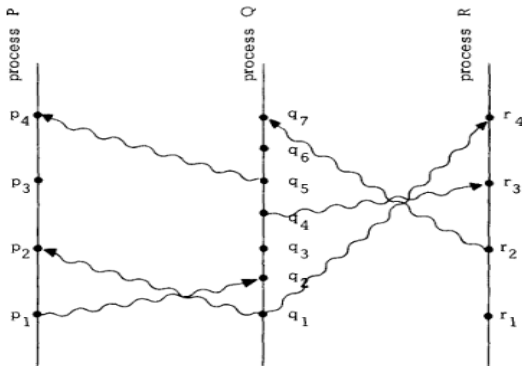
# Logical Clock (Lamport Algorithm)

- Provide **happened before** relationship

$$a \rightarrow b$$

- Total Ordering

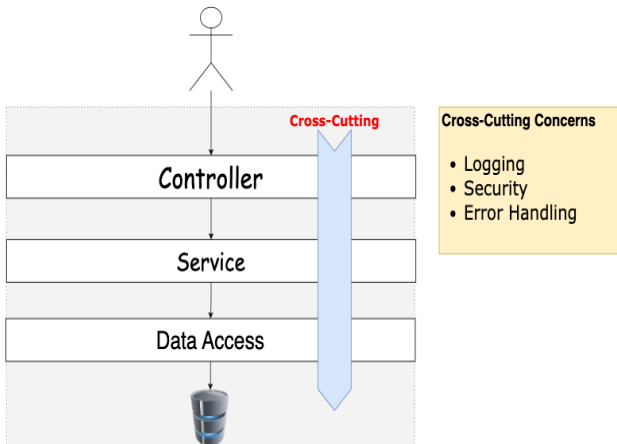
$$a \Rightarrow b \iff a \rightarrow b$$



# Distributed System Security



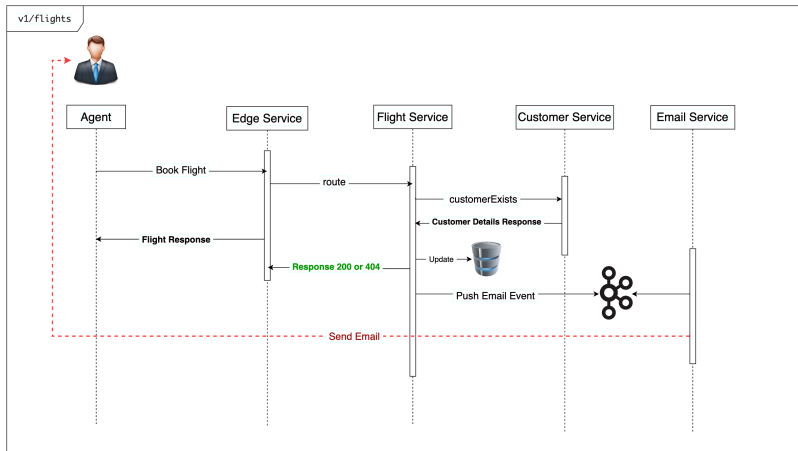
# Distributed System Security



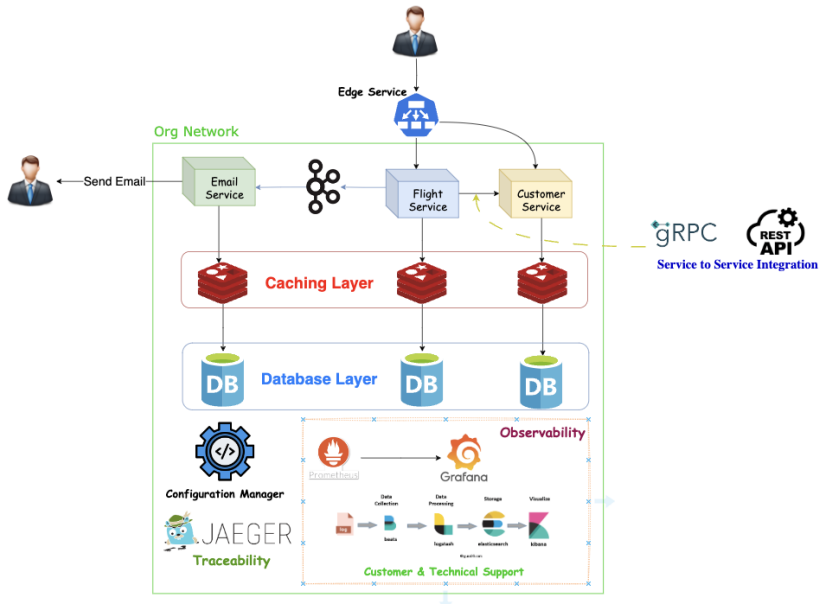
# Distributed System Monitoring

- Log aggregation and distributed tracing
- Metrics collection and monitoring tools (e.g., Prometheus, Grafana)
- Anomaly detection and performance optimization

# API Documentations



# Recap



# Conclusion

- Recap of distributed systems concepts
- Overview of various distributed systems topics
- Further resources for exploring distributed systems in depth